US Army Corps of Engineers ®
Walla Walla District

MILL CREEK FLOOD RISK MANAGEMENT GENERAL INVESTIGATION

Draft Feasibility Study and Environmental Assessment Report

January 2020

APPENDIX C
ECONOMICS

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MILL CREEK FLOOD RISK MANAGEMENT GENERAL INVESTIGATION FEASIBILITY STUDY AND ENVIRONMENTAL ASSESSMENT REPORT – DRAFT APPENDIX C, ECONOMICS

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ACRONYMS AND ABBREVIATIONS

AAB	Average annual benefits
AAC	Average annual costs
ACS	American Community Survey
AEP	Annual exceedance probability
BCR	Benefit-to-cost ratio
cfs	Cubic feet per second
Corps	U.S. Army Corps of Engineers
CSVR	Content to structure value ratio
CWCCIS	Civil Works Construction Cost Index System
DDF	Depth-damage function
DOT	Department of Transportation
EAD	Expected annual damages
EC	Engineering Circular
EGM	Economic Guidance Memorandum
EM	Engineer Manual
ER	Engineer Regulation
ERR	Economic Reevaluation Report
FEMA	Federal Emergency Management Agency
FIA	Flood Insurance Administration
FRM	Flood risk management
FY	Fiscal year
GIS	Geographic Information System
H&H	Hydraulics & Hydrology
HEC-FDA	Hydrologic Engineering Center – Flood Damage Analysis
HEC-RAS	Hydrologic Engineering Center – River Analysis System
IDC	Interest during construction
IWR	Institute for Water Resources
MCFCP	Mill Creek Flood Control Project
MMC	Modeling, Mapping and Consequences
NADA	National Automobile Dealers Association
NED	National Economic Development
NFIP	National Flood Insurance Program
NWD	Northwestern Division
OMRR&R	Operation and maintenance, repair, replacement and rehabilitation
OSE	Other Social Effects
PAR	Population at risk
PDT	Project delivery team
RED	Regional Economic Development
TSP	Tentatively Selected Plan
USACE	U.S. Army Corps of Engineers
WRDA	Water Resources Development Act

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SECTION 1 - INTRODUCTION

The U.S. Army Corps of Engineers (Corps), Walla Walla District, and the non-Federal Sponsor, Mill Creek Flood Control Zone District (Walla Walla County), conducted a flood risk management study to address the increased risks Mill Creek presents to the community of Walla Walla, Washington, and other communities within the Mill Creek Watershed (adjacent lands). This Economics Appendix presents the results of the flood management alternatives analysis performed to evaluate potential improvements to the existing Mill Creek Flood Control Project (MCFCP).

1.1 PURPOSE

This feasibility-level economic analysis provides a benefit-cost analysis of the proposed project. Demographic data and economic development background pertaining to the community are presented, and the development of a complete structure inventory is discussed. The inventory serves as the basis for a risk-based analysis which evaluates flood damages in the study area on an annualized expected basis and calculates damage reduction project performance by simulating a large number of possible flood events, taking into account all pertinent economic and engineering data including uncertainty factors. This analysis results in several outputs:

- Description and quantification of economic and social flood damage impacts to properties within the study area in the existing condition.
- Statistical estimates of project engineering performance or reliability under existing conditions in the context of a range of possible flood events.
- Estimated economic performance of alternatives formulated to improve project performance, in terms of residual damages, damages prevented, annualized benefits and costs.
- Statistical estimates of enhanced project engineering performance provided by each alternative.
- Economic optimization of alternatives and identification of the most economically efficient alternative.
- Characterization of the selected plan in terms of economic performance (annual damages, benefits, costs and residual damages) and engineering performance (or assurance).

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1.2 STUDY GUIDANCE

Pertinent guidance governing economic analysis procedures includes:

- Engineer Circular (EC) 1165-217, Review Policy for Civil Works, 20 Feb 2018.
- Engineer Circular (EC) 1165-2-218 Levee Safety Program – Policy and Procedures, DRAFT, 10 Mar 2018.
- Economic Guidance Memorandum (EGM) 01-03, Generic Depth-Damage Relationships, 4 Dec 2000.
- Economic Guidance Memorandum (EGM) 04-01, Generic Depth-Damage Relationships for Residential Structures with Basements, 10 Oct 2003.
- Economic Guidance Memorandum (EGM) 09-04, Generic Depth-Damage Relationships for Vehicles, 22 Jun 2009.
- Engineer Manual (EM) 1110-2-1619, Risk-Based Analysis for Flood Damage Reduction Studies, dated 1 Aug 1996.
- Engineer Regulation (ER) 1105-2-100, Planning Guidance Notebook, 22 Apr 2000.
- Engineer Regulation (ER) 1105-2-101, Risk Assessment for Flood Risk Management Studies, 17 July 2017.
- Engineer Regulation (ER) 1110-2-1156, Safety of Dams – Policy and Procedures, 31 Mar 2014.
- Engineer Regulation (ER) 1165-2-26, Implementation of Executive Order 11988 on Flood Plain Management, 30 Mar 84.
- Institute for Water Resources (IWR) Report 96-R-12, Analysis of Nonresidential Content Value and Depth-Damage Data for Flood Damage Reduction Studies, May 1996.
- Water Resources Development Act (WRDA) of 1990, Sec. 308 Flood plain management, 28 Nov 1990.

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SECTION 2 - STUDY AREA LOCATION

2.1 LOCATION

The city of Walla Walla is located along the border of southeastern Washington and northeastern Oregon. Mill Creek originates near the border of Washington and Oregon and flows west for 33 miles before its confluence with the Walla Walla River, which flows west for 33.5 miles before entering the Columbia River. Major tributaries of Mill Creek include Paradise, Tiger, Blue, and Titus Creeks, and distributaries include Titus, Yellowhawk, and Garrison Creeks (Garrison is actually a distributary of Yellowhawk, originating about 0.1 miles beyond Yellowhawk's origin). Russell Creek also can receive some water from Mill Creek after large floods. Most of the Mill Creek Watershed is within Walla Walla County in Washington, but it also includes parts of Columbia County in Washington, and Umatilla and Wallowa Counties in Oregon. Figure 2-1 below includes a map of the Mill Creek and major tributaries.

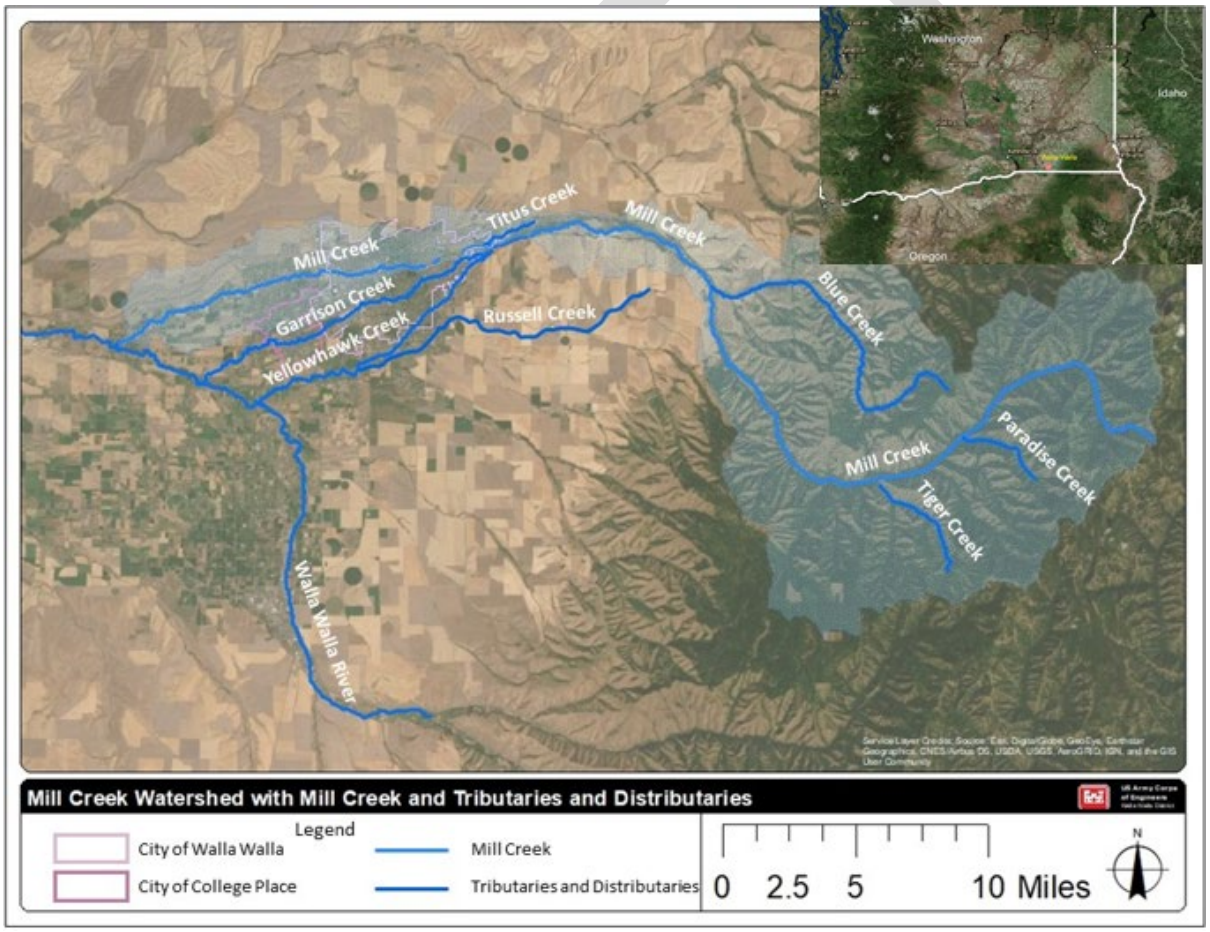

Figure 2-1. Study Area Location

2.2 SOCIOECONOMIC CONTEXT

The purpose of this section of the report is to present the socioeconomic context for the Mill Creek study area. Background information helpful for understanding the land use conditions,

people and community that exists within the Mill Creek study area are provided. Land use types and location are important for understanding where people live and work within study area boundaries, while demographic and socioeconomic data is helpful for understanding the population who reside within or around the Mill Creek area. Following these background sections, the analysis completed to assess flood risk conditions for existing and future without project conditions are provided, followed by the analysis of alternatives under with-project conditions. A summary of the benefit-cost and net benefit analysis is then provided.

2.2.1 Mill Creek Land Use

Mill Creek consists of 102.8 square miles located in Walla Walla County including the Walla Walla Metropolitan Area and flows in a southwesterly direction through a mixture of residential and commercial areas to the Columbia River near Wallula. Figure 2-2shows land use by parcel of the City of Walla Walla used specifically for economic analysis.

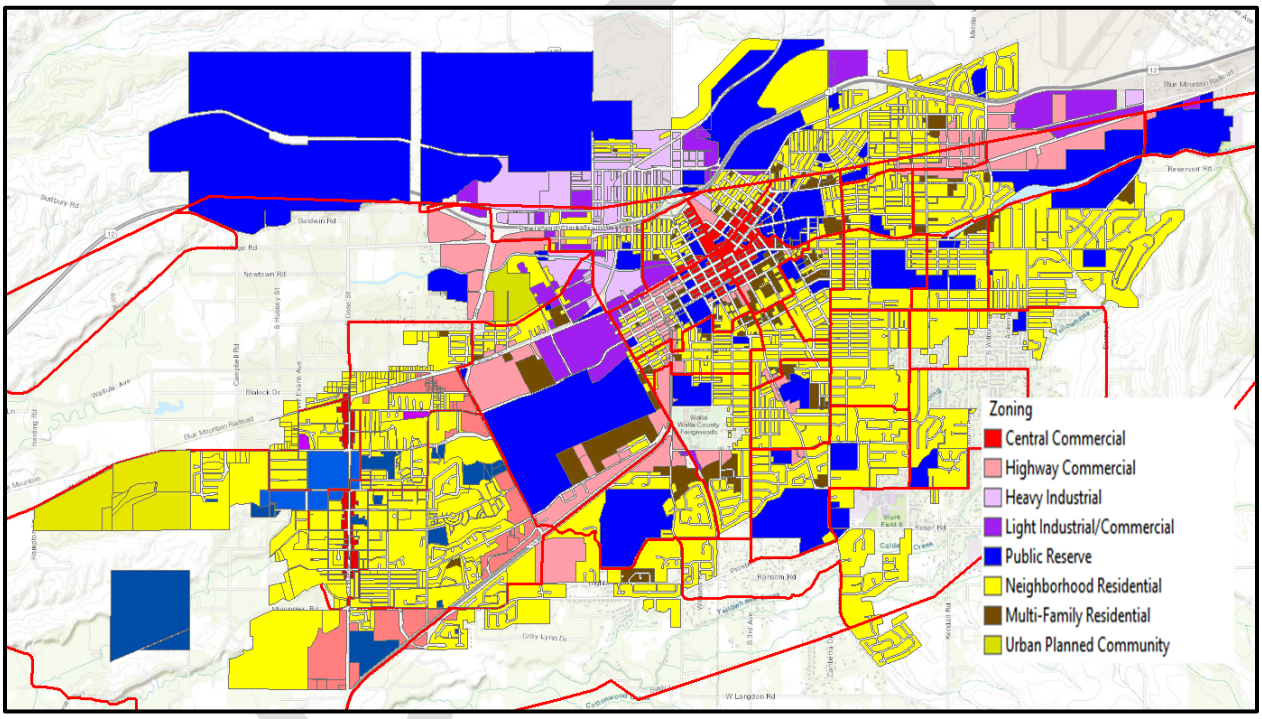

Figure 2-2. City of Walla Walla Land Use

The primary non-agricultural land uses in Walla Walla are industrial (18 percent), future development (15 percent), and residential (13 percent). Table 2-1 summarizes by the land use by total acres and percent of total.

Table 2-1. Land Use Data

Land Use	Acres	Percent
Agriculture	5,978	35%
Aviation	174	1%
Commercial	1,385	8%
Future Development	2,563	15%
Government	243	1%
Industrial	3,103	18%
Mixed	554	3%
Multi-Residential	525	3%
Other	0	0%
Railroad	260	2%
Residential	2,224	13%
Total	17,009	100%

2.2.2 Population and Housing

Socioeconomic and demographic information gathered for the Mill Creek study relies heavily upon data obtained from the U.S. Census Bureau. The boundaries of the 0.1 percent (1/100 year) annual exceedance probability (AEP) floodplain extent are used as the basis for gathering socioeconomic and demographic conditions for Mill Creek. The most recent Census data available is from the 2013-2017 American Community Survey (U.S. Census Bureau 2019). The American Community Survey includes data at the *block group* level. Figure overlays the Mill Creek study area and the census block group geographic areas. Block group level data provides a reasonable approximation of population and housing unit counts for the Mill Creek study area (from the 2010 Census). There are 37 census block groups intersecting the Mill Creek 0.1 percent AEP study area.

Table 2-2 summarizes population and housing unit counts for Mill Creek study area. Based on census block group data, the study area is home to approximately 52,371 residents, or about 89 percent of the county's total population. The population density of the study area (509 persons per square mile) is below that of city as a whole (2,478 persons per square mile).

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Table 2-2. Population and Housing Unit Summary

Locality	Census Block Groups	Area (sq mi)	2010 Population	Population Density (per sq mi)	2010 Households
Mill Creek Study Area	37	102	46,865	509	19,911
City of Walla Walla		123	32,585	2,478	11,537
Walla Walla County		1,270	58,781	46	21,719
Washington		66,455	6,724,540	101	2,620,076
United States		3,800,000	308,754,538	81	116,716,292

Source: U.S. Census Bureau, 2010 Census

Table 2-3 summarizes housing units by occupancy type. Based on block group data, the home ownership rate (58 percent) is slightly higher than citywide (53.06 percent) as well as the State of Washington (56.8 percent), but lower than Walla Walla County (59.35 percent). The vacancy rate is lower than all other geographic areas at 7.59 percent.

Table 2-3. Housing Unit Summary

Locality	Owner Occupied Percentage	Renter Occupied Percentage	Vacant Percentage
Mill Creek Study Area	57.96%	34.45%	7.59%
City of Walla Walla	53.06%	38.63%	8.30%
Walla Walla County	59.35%	32.59%	8.10%
Washington	57.08%	34.00%	8.90%
U.S	56.00%	31.80%	12.20%

Source: U.S. Census Bureau, 2013-2017 American Community Survey 5-Year Estimates

Table 2-4 summarizes race in the Mill Creek study area. Based on block group data, the study area is comprised primarily of those identified as White Alone (68.44 percent), Hispanic or Latino (21.68 percent), or Two or more races (6.28 percent). For most minority populations, the Mill Creek study area includes a similar proportion of minority populations compared to the City of Walla Walla and Walla Walla County. More discussion of the potential impacts to minority and low income populations is included in the Other Social Effects section.

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Table 2-4. Population and Housing Unit Summary

Ethnicity	Mill Creek Study Area	City of Walla Walla	Walla Walla County	Washington	United States
Hispanic or Latino (of any race)	21.68%	24.60%	21.10%	12.30%	17.60%
White alone	68.44%	66.50%	72.30%	69.80%	61.50%
Black or African American alone	1.41%	2.00%	1.40%	3.50%	12.30%
American Indian and Alaska Native alone	0.52%	0.50%	0.50%	1.10%	0.70%
Native Hawaiian and Other Pacific Islander Alone	1.39%	2.10%	1.50%	8.00%	5.30%
Some other race alone	0.07%	0.10%	0.10%	0.60%	0.20%
Two or more races	0.21%	0.10%	0.20%	0.10%	0.20%

Source: U.S. Census Bureau, 2013-2017 American Community Survey 5-Year Estimates

2.2.3 Employment and Income

Similar to demographic information, employment and income characteristics are available only by block group or higher (level of geographic area). Table 2-5 summarizes employment and income information for the 37 block groups intersecting the study area as well as at the city, county, state and national level. The Mill Creek study area block groups reflect higher than average income and home value, an average poverty rate and a lower unemployment rate compared to most of the other geographic areas besides the City of Walla Walla.

Table 2-5. Employment and Income

Locality	Median Household Income ($)	Unemployment Rate (%)[1]	Poverty Rate (%)[2]	Median Home Value ($)[3]
Mill Creek Study Area	$51,133	5.69%	16.31%	$194,071
City of Walla Walla	$46,650	6.80%	18.70%	$178,800
Walla Walla County	$52,630	6.00%	14.40%	$196,300
Washington	$80,233	6.00%	12.20%	$286,800
U.S	$57,652	4.10%	10.50%	$193,500

Source: U.S. Census Bureau, 2013-2017 American Community Survey 5-Year Estimates
1. for median household income unemployment rate and poverty rate, weighted average based on total population
2. of all families
3. for owner-occupied units, weighted average based on total owner occupied units

Table 2-6 summarizes employment by industry by census tracts in the Mill Creek study area as well as at the city, county, state and national level. The study area has very similar rates of employment in most industries, when compared to the city and county as a whole.

Table 2-6. Employment by Industry

Ethnicity	Mill Creek Study Area	City of Walla Walla	Walla Walla County	Washington	United States
Civilian employed population 16 years and over	23,124	13,479	26,496	3,418,123	150,599,165
Agriculture, forestry, fishing and hunting, and mining	5.71%	3.90%	6.50%	2.60%	1.90%
Construction	5.41%	5.30%	6.10%	6.30%	6.40%
Manufacturing	6.84%	7.90%	7.90%	10.30%	10.30%
Wholesale trade	2.21%	2.10%	2.50%	2.90%	2.70%
Retail trade	11.24%	10.30%	10.00%	11.80%	11.40%
Transportation and warehousing, and utilities	2.68%	2.80%	3.40%	5.20%	5.10%
Information	5.37%	0.90%	1.20%	2.30%	2.10%
Finance and insurance, and real estate and rental and leasing	5.37%	4.50%	3.90%	5.40%	6.60%
Professional, scientific, and management, and administrative and waste management services	6.55%	9.50%	7.70%	12.60%	11.30%
Educational services, and health care and social assistance	31.97%	32.30%	31.70%	21.60%	23.10%
Arts, entertainment, and recreation, and accommodation and food services	7.33%	10.40%	8.60%	9.20%	9.70%
Other services, except public administration	3.80%	3.60%	3.70%	4.60%	4.90%
Public administration	6.44%	6.60%	6.70%	5.10%	4.70%

Source: U.S. Census Bureau, 2013-2017 American Community Survey 5-Year Estimates

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2.3 HISTORIAL FLOODING ON MILL CREEK

Major floods have occurred on Mill Creek in March 1931, December 1964, and February 1996. The 1931 flood was the largest pre-Project flood in Walla Walla County and caused Mill Creek to flow through the streets of the City of Walla Walla as can be seen in Figure 2-3. To address the need for flood risk management, continuous retaining walls through the city were completed in 1933 and the Mill Creek Flood Control Zone District was organized in 1935 to assume flood management responsibilities. Between 1935 and 1939, the Mill Creek channel through the middle of Walla Walla was constructed by the Works Progress Administration. The president of the Walla Walla Chamber of Commerce, Virgil B. Bennington, lobbied Congress for better flood protection for the city due to ongoing flooding concerns. Congress authorized the Project in the Flood Control Act of 1938. Project construction was completed in 1942.

Figure 2-3. Flood of 1931

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SECTION 3 - FRAMEWORK OF ECONOMIC ANALYSIS

The economic analysis and how it relates to the study purpose and related objectives is described in this section. An overview of the economic analysis used to evaluate the flood risk management alternatives are described in this section, along with the models and tools used to perform the economic analysis.

3.1 ECONOMIC ANALYSIS METHODOLOGY AND PARAMETERS

Economic costs and benefits associated with an alternative are evaluated in terms of their impacts on national wealth, without regard to where in the United States the impacts may occur. National Economic Development (NED) benefits must result directly from a project and must represent net increases in the economic value of goods and services to the national economy, not simply to a region or locality. Using the 50-year period of analysis, and the current federal discount rate, expected annual damages (EAD) or damages reduced (i.e. benefits) are calculated.

NED costs represent the costs of diverting resources from other uses in implementing the project, as well as the costs of uncompensated economic losses resulting from detrimental effects of the project. NED annual benefits, the benefit-cost ratio, and the net NED annual benefits are calculated during the evaluation process. Net benefits represent the amount by which the NED benefits exceed NED costs, thereby defining the plan's contribution to the nation's economic output. A benefit-cost ratio of 1.0 or greater must be demonstrated for a Federal interest. The plan with the highest net benefits is considered the recommended plan, assuming technical feasibility, environmental soundness, and acceptability

3.1.1 Price Level, Period of Analysis, and Discount Rate

Values listed in this document are based on fiscal year (FY) 2020 price levels unless otherwise noted. Annualized benefits and costs are computed using a 50-year period of analysis and the FY 2020 federal discount rate of 2.75 percent.

3.1.2 Economic Analysis Tool: HEC-FDA Risk Analysis Program

The Mill Creek economic analysis uses the Hydrologic Engineering Center Flood Damage Analysis (HEC-FDA) program to compute damages and benefits. This USACE certified risk-based program is standard for flood-risk evaluation studies. The most current certified version of HEC-FDA, 1.4.2, is used for this analysis. This program applies engineering data (hydrologic, hydraulic, and geotechnical when applicable) and economic data (structure/content inventory and depth-percent damage curves) to model the potential flood risk and potential alternative solutions for the study area, while also incorporating risk and uncertainty.

Risk is a function of both probability and consequence, and the fact that risk inherently involves chance leads directly to a need to describe and plan for uncertainty. USACE policy requires incorporating risk and uncertainty in anticipating floods and their impacts. The determination

of EAD for a flood risk management study takes into account complex and uncertain hydrologic, hydraulic, geotechnical, and economic information, including:

- Hydrologic - The discharge-frequency function describes the probability of floods equal to or greater than some discharge quantity.
- Hydraulics - The stage-discharge function describes how high (stage) the flow of water may be for a given volume of flow discharge.
- Economics - The stage-damage function describes the amount of damage that might occur given certain floodplain stages.

The HEC-FDA program computes the EAD calculation by following a process depicted in Figure 3-1. To find the damage for any given flood frequency, the discharge for that frequency is first located in the discharge-frequency graph (1. Hydrology), then the river channel stage associated with that discharge value is determined in the stage-discharge graph (2. Hydraulics). Next the stages (water depths) in the floodplain are compared with economic input (elevations, property values) to determine potential damage at associated stages (lower left graph). The HEC-FDA program utilizes a Monte Carlo process to randomly sample multiple probability distribution functions to produce tens of thousands of possible flood events. By plotting this damage and repeating for process numerous iterations (via Monte Carlo simulation), the damage-frequency curve is determined (lower right graph). EAD is then computed by finding the area under the flood damage-frequency curve by integration for the without and with project conditions. The calculation of annual damages conceptually involves a weighted average in which damages computed for each event are multiplied by the incremental probability of that event and the product is summed. This EAD represents an estimate of the average damages that would be expected in any given year over the long term. Reduction in EADs for the 'with project condition' are flood risk management benefits.

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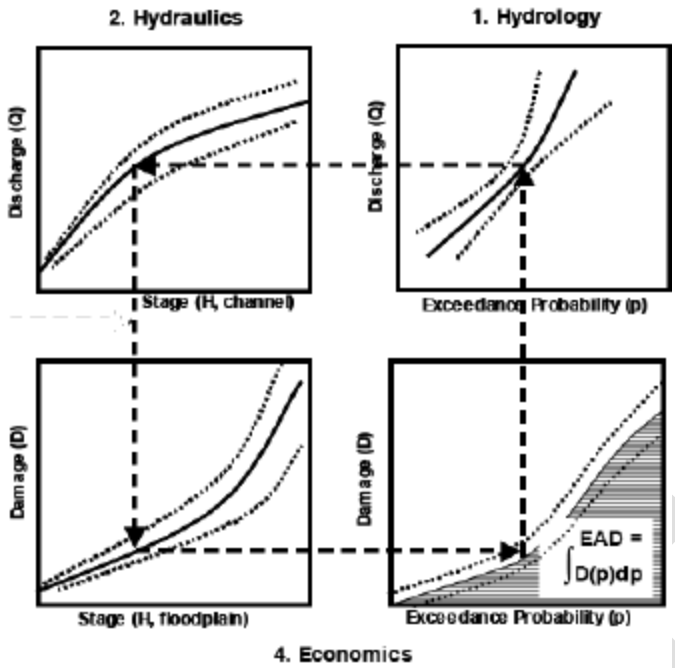

Figure 3-1. Discharge, Stage and Damage Relationships for Determining EAD

The results of the HEC-FDA modeling are then used as input into calculating the net average annual benefits and benefit-to-cost calculations, which are all performed external to HEC-FDA.

3.1.3 Multiple Source Flooding into Single Consequence Area

Multiple sources of flooding within a single consequence area complicate the economic risk analysis in terms of estimating the chance of flooding and the consequences of flooding in the area. Additional analytical complexity is introduced if one considers that the probability of flooding along a particular flooding source also varies (i.e., not only is the probability of flooding between various water sources not uniform but the probability of flooding along a specific water source is also not uniform), and that the same area could be flooded from a failure occurring at different locations but with varying magnitudes (i.e., different floodplains) depending on the type and location of the failure.

The risk analysis was performed using multiple index points, with each point tied to a specifics source of flooding within the study area. The same index points were used for both the without-project and with-project analyses

3.1.4 Economic Reaches and Index Locations

Walla Walla is at risk of flooding from multiple sources. Additionally, along each source of flooding, the condition of the levee or channel could vary from one location (hydraulic reach) to the next, with the probability of flooding from a particular reach varying correspondingly.

In terms of economic analysis, levee reaches are used to focus-in on those areas deemed most pertinent for developing engineering data, which feed into the economic modeling. Data are generated at representative index points within each reach and are used to estimate project performance statistics under both without-project and with-project conditions. The engineering data is also used in conjunction with economic data to estimate expected damages and benefits. Both sets of results are then used together to describe the flood risk in the study area.

The project delivery team (PDT) selected hydraulic/geotechnical reaches to each contain one index point for generating engineering data for use in the economic model. These index points were selected to aid in a more accurate description of residual flood risk in the study area. The index points used in the economic analysis are shown in Table 3-1. Since the inundation mapping for the pipe column and ceiling cover failure modes would be the virtually identical, the same index point was used for both.

Table 3-1. Index Stations by Failure Mode

Failure Mode	Index Station
Pipe Column	8.1830
Ceiling Cover	8.1830
Otis Street Blockage	8.6900
Tausick Way	10.9688
Yellowhawk	11.5168

3.2 DATA DEVELOPMENT

3.2.1 Initial Database Development

The economic database for the Mill Creek analysis was based initially on data from Walla Walla County tax records which included structures in the study area along with supporting data in the form of structure characteristics for each property. The following datasets were the primary sources of structure and land use information:

- Parcel database: parcel polygons with associated tabular data, in GIS format.
- Real property database: additional property characteristics in a text file (not included in the GIS), but linked using Assessor's parcel number.
- Secondary property database: additional tabular dataset received from the Assessor's Office, linked to parcels via parcel number.
- Building outlines shapefile: GIS layer including outlines of buildings and limited building characteristics.

A GIS-based Building Outline shapefile was used to identify individual structures and create structure centroids in GIS. In order to link the data in the parcel database, real property database, and secondary property database with centroids generated from the building outlines, Microsoft Excel was used to create a single large database that combined all four datasets. The resulting structure inventory database includes all existing information for each parcel, attributed to each structure.

The data includes structures within the 0.1 percent (1,000-Year) annual chance exceedance (AEP) floodplain. In total, over 14,835 structures are included in the structure inventory database. It should be noted that Section 308 of the Water Resources Development Act (WRDA) of 1990 has been observed in this analysis, and structures built since 1991 in the one percent AEP floodplain are assumed to be in compliance with Section 308 due to the study area's communities' participation in the National Flood Insurance Program (NFIP). Assessor's data was used to determine the age of the structure.

3.2.2 Structure Occupancy Types

A structure occupancy type in HEC-FDA is a subcategory of individual study damage categories and is a name given to a similar set of structures that is used to define depth-percent damage functions, first-floor uncertainties, structure value uncertainties, content-to-structure value ratios with uncertainties, and other-to-structure value ratios with uncertainties for each type of structure.

3.2.3 Elevations and Stationing

Each property in a flood-risk management economic analysis is assigned a ground elevation at mean sea level, as well as a first-floor elevation and a lowest opening elevation if it is different from the first-floor elevation. Each structure point was overlaid onto the grid-cells of the 2D HEC-RAS modeling to assign each structure a station that associates with a set of eight water surface elevation grids. The elevations and stations are used in the flood damage analysis model to help determine depths of flooding for each flood event evaluated. First floor elevations were determined using Walla Walla County Appraiser photos and Google Earth Street View for all single family residential homes, mobile homes, and multi-family and non-residential structures. The averages of the samples were applied to all structures of those types that were not sampled.

The first-floor elevations for each type of structure are assigned an uncertainty factor, usually expressed as a standard deviation around a normally distributed variable. A standard deviation of the error associated with the first floor elevation must be assigned in HEC-FDA to account for the uncertainty in the height of the first floor above ground. Ground elevations were assigned in accordance with EM 1110-2-1619 dated 1 August 1996. A standard deviation of 0.5 feet is estimated for the error associated with first flood elevations.

3.2.4 Structure Valuation

Following USACE planning guidance, structure valuation for estimating flood damage is based on current depreciated replacement value. Depreciated replacement value is used to reflect the actual value subject to damage as opposed to full replacement cost which would reflect a betterment relative to the actual condition.

The depreciated replacement value for residential and non-residential structures is estimated using structure attribute data, county assessor data, field observations, and regional building cost data. Specific variables used to calculate the depreciated replacement values are construction material (i.e. masonry, wood, etc.), quality of construction, and square footage which is used in conjunction with the unit cost to estimate replacement cost. Structure depreciation is estimated and included in the replacement cost, along with a locality adjustment (Spokane, WA). Initial preliminary alternatives modeling incorporated values based on assessor valuations only, with a small percentage of structures having a depreciated replacement value if one was not provided in the assessor's data. Since the initial modeling, a stratified sample based on structure type was taken and enough structures in each type were individually valued using RSMeans and Marshall and Swift (M&S) to establish a 95 percent confidence based on the central limit theorem. Below details how non-residential, single family residential, and mobile residential structures were sampled. Table 3-2 displays the total number of structures in each structure type, the sample size needed to establish a 95 percent confidence interval, and the number of structures sampled.

Table 3-2. Structures Sampled by Type

Structure Type	Total Structures	95% Confidence Interval	Structures Sampled
Residential	12,376	373	2,479
Non-residential	1,560	309	383
Mobile Homes[1]	899	-	-
Total	14,835	682	2,862

[1] Since the parcel data does not break out mobile home parks by individual structure, a sample of assessor's data was not possible. Given the relatively low value of structures and historical data, it was determined that a comprehensive windshield survey would add marginal value at an enormous cost.

Non-residential structures include commercial, industrial, public, and multi-family apartment buildings. Non-residential structure building cost data was obtained from the 2019 Marshall & Swift, Inc. Real Estate Valuation Database. The study area includes 1,560 non-residential structures of which 383 were sampled and valued using structure data from the county assessor, ArcGIS, and Google Earth Street View. During the initial sampling, there were significant differences between the calculated depreciated replacement values and assessor values for parcels with more than one structure. Therefore, an additional 74 parcel sharing structures showing inundation at the 0.1 percent (1,000-Year) AEP event were added to the non-residential sample in order to decrease uncertainty in structure values. Then an index of 1.11 was applied to the remaining non-residential structures not sampled based on the

difference between total depreciated replacement value calculated and the assessor's value for the 383 sampled structures.

Single family residential structure building costs data uses the 2019 RSMeans Residential Cost Database to calculate the depreciated replacement value. The study area includes 12,376 single family residences, excluding mobile homes, of which 2,479 were sampled and valued using structure data from the county assessor, ArcGIS, and Google Earth Street View. After initially sampling 373 structures, the assessor value for 52 structures was significantly lower than the calculated depreciated replacement value. Therefore, all single family residential structures showing inundation at the 0.1 percent (1,000-Year) AEP event were added to the sample to decrease uncertainty for residential structure values. Then an index of 1.03 was applied to the single family residential structures not sampled based on the difference between total depreciated replacement value calculated and the assessor's value for the 2,479 sampled structures.

In addition to non-residential and single family structures, the study area includes 899 mobile homes. The assessed value of mobile homes was low based on multiple structures on the same parcel. The average value using the assessor's database was $12,910 with the majority (740) of mobile homes sharing a parcel in a mobile home park with an average value of $10,708. After comparing mobile homes in the study area to mobile homes in other Corps studies, it was determined to value all structures categorized as mobile home at $20,000.

Even after sampling by structure type, there is uncertainty in the depreciated replacement values for structures due to factors such as assessment of construction types and qualities. In order to account for this, uncertainty measures were assigned to structure values, as suggested in Corps EM 1110-2-1619. Residential and non-residential structure values were assumed to be normally distributed with a standard error (standard deviation in percent) of 25 percent. Data from previous studies within the Northwestern Division, as well as professional judgment, were used to calculate the standard deviation of the depreciated replacement values for structures in the HEC-FDA risk model.

3.2.5 Contents Valuation

The generic content depth-damage curves for residential structures provided in the Economic Guidance Memorandum (EGM) 04-01, *Generic Depth-Damage Relationships for Residential Structures with Basements*, October 2003, represented the content depth-damage functions for residential structures in HEC-FDA. Using these relationships, it is not necessary to define the value of contents for a residence in HEC-FDA. Uncertainty was applied to the content-to-structure value ratios as specified in Corps EM 1110-2-1619 to account for variation among structures within each occupancy type. Based on guidance from EGM 04-01, the "error associated with content/structure" value was left blank, which implies that the error in content-to-structure value ratio is part of the content depth-damage relationship. For purposes of estimating investment only, the residential content-to-structure value ratio (CSVR) used is 50 percent. For mobile homes, which are not included in the IWR functions, a CSVR of 139 percent is used.

CSVRs for nonresidential structures were derived from the American River Economic Reevaluation Report (ERR) completed by Sacramento District were utilized for this study and ranged from 26.1 percent to 251.1 percent of the structure value. As a part of the ERR, Sacramento completed an expert elicitation to develop CSVRs and content damage functions that better reflect the land use in the region. Upon review of these CSVRs and content damage functions, the Walla Walla District determined that they were a more appropriate fit for the land use seen in this study region as opposed to CSVRs and damage functions that are based on more general, national level characteristics. Table 3-3 below lists the occupancy types and their respective CSVRs used in the analysis.

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Table 3-3. Occupancy Types and Content-to-Structure Value Ratios

Occupancy Code	Description	CSVR (%)	Occupancy Code	Description	CSVR (%)
NR01	Clothing Retail Store	66.8	NR29	Recreational Facility	171.9
NR03	Convenience Store	54.4	NR31	Religious Facility	26.1
NR05	Correctional Facility	45.4	NR33	School	50.0
NR07	Electronic Retail Store	66.8	NR35	Service Station	251.1
NR09	Fast Food Restaurant Engineered	54.6	NR37	Warehouse, Non-Refrigerated Engineered	116.3
NR10	Fast Food Restaurant Pre-Engineered	54.6	NR38	Warehouse, Non-Refrigerated Pre-Engineered	116.3
NR11	Furniture Retail Store	72.0	NR39	Warehouse, Refrigerated	116.3
NR13	Grocery	138.4	R01	Residential - 1 Story With Basement	50.0
NR15	Hospital	120.1	R02	Residential - 2 Story With Basement	50.0
NR17	Hotel	89.5	R03	Residential - Split Level With Basement	50.0
NR19	Industrial Light Manufacturing	244.0	R04	Residential - 1 Story No Basement	50.0
NR21	Medical Office	192.3	R07	Mobile Homes	139.0
NR23	Non-Fast Food Restaurant	174.3	R08	Apartments - 1 Story With Basement	50.0
NR25	Office Building Engineered	44.4	R09	Apartments - 2 Story With Basement	50.0
NR26	Office Building Pre-Engineered	44.4	R10	Apartments - 1 Story No Basement	50.0
NR27	Protective Services	45.4	R11	Apartments - 2 Story No Basement	50.0

Note: Structures are currently assigned a Non-Residential ("NR") or Residential ("R") damage category for aggregating damages. Non-Residential will be further disaggregated into other categories in optimization.

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3.2.6 Vehicles Valuation

Appurtenant uses such as vehicles, equipment, and landscaping can be accounted for in HEC-FDA. For this particular study only the value of vehicles associated with residential structures was evaluated. Using Microsoft Excel add-ins PrecisionTree and @RISK Version 7.5, a model was developed to incorporate the cost of vehicles that may be damaged during flood events. The model incorporates vehicle segment data, age of vehicles on the road, historical average transaction prices, and depreciation curves based on age to estimate the average value of vehicles in the study area.

First, percentages of vehicle types split into segments were obtained using National Automobile Dealers Association (NADA) databases published on Statista. In addition, historical new vehicle pricing by vehicle segment was estimated using the 2018 Kelly Blue Book average transaction price by segment and adjusting the 2018 price level using New Vehicle Consumer Price Index for a total of 20 years. The different vehicle segments were then consolidated into three different categories; Trucks/SUVs, Crossovers/Vans, and Cars. Next, vehicle age data from National Household Travel Survey was incorporated to define the age distribution of vehicles on the road. Finally, using @RISK a triangular depreciation curve was created using high, medium, and low depreciation rates from gigacalculator.com. The curves were then applied to each vehicle segment based on the age distribution of vehicles by depreciating the historical adjusted price. Vehicle values for multi-residential structures was assumed to be 10 percent of the structure value. This assumption is used for preliminary alternatives screening and is a conservative estimate of vehicles at multi-family residential structures. Further refinement of vehicle counts for multi-family residential structures will occur for the selected plan.

The model estimated an average vehicle value of around $18,000 per vehicle. According to a 2014 Road Usage Charge Assessment conducted by the Washington State Transportation Commission the average vehicles per household is 2.3 statewide. Assuming that one vehicle would be removed during a flood event, the assumption was made that one vehicle per structure would remain due to the relatively short response and evacuation times.

3.2.7 Roads and Railroads Valuation

Roads are perhaps the most commonly damaged infrastructure in a flood event. Damage to highways may be caused by floodwaters overtopping, eroding and scouring road surfaces, shoulders, and embankment slopes. In addition to obvious washout areas, as the ground begins to dry out after flooding, pavement buckling and other problem areas can become apparent. Miles of roads and highways were determined by clipping the TIGER/Line road shapefile to the Mill Creek Watershed study area. Estimates of the average investment per mile for the various types of roads were developed from road construction cost estimates recently obtained from the Department of Transportation (DOT) and were applied to the estimated miles of roadways by type subject to flooding. Uncertainties in investment value were determined based on the ranges of values provided for the different types of roads. The analysis uses a 10 percent maximum or minimum variation for interstates and major highways based on the DOT estimates. The values by roadway type and source are shown in Table 3-4.

Table 3-4. Roadway Construction Costs (in millions)

Roadway Type	Rural (Low)	Rural (Median)	Rural (High)	Urban (Low)	Urban (Median)	Urban (High)
2-Lane Undivided Road	$2.0	$2.5	$3.0	$3.0	$4.0	$5.0
4-Lane Highway	$4.0	$5.0	$6.0	$8.0	$9.0	$10.0
6-Lane Interstate Highway		$7.0			$11.0	
Mill / Resurface 4-Lane Road		$1.25			$1.25	
Expand Interstate Highway		$4.0			$4.0	

Source: https://www.artba.org/about/faq/

Data for railroad tracks were developed in a similar manner. Miles of track were determined by clipping the TIGER/Line road shapefile to the study area. Estimates of investment value per mile were based on previous Northwestern Division studies that relied on data obtained during interviews with railroad representatives. This estimate, $2.275 million, was updated to current price levels based on Civil Works Construction Cost Index System (CWCCIS) values for Roads, Railroads, and Bridges. Minimum and maximum uncertainties of 37.5 percent were input based on the range of values obtained from the railroad representatives interviewed. Discussions with railroad officials confirmed this valuation was reasonable while suggesting the uncertainty may even be greater as recent reconstruction efforts have cost as much as $7 million per mile.

3.2.8 Damage Functions: Residential

Depth-damage curves relate the percent of structure and content value that is damaged given the depth of inundation. Economic Guidance Memorandum (EGM) 04-01, *Generic Depth-Damage Relationships for Residential Structures with Basements*, October 2003, represented the depth-damage functions for residential structures in HEC-FDA.

This EGM summarized data developed by the Institute for Water Resources (IWR) using post-flood residential damage claim records provided by the Federal Emergency Management Agency (FEMA). The functions account for both structural and content damage to homes with and without basements.

A depth-damage curve for mobile homes is not included in EGM 04-01. Instead, the damage curve for mobile homes based on 2006 data from the New Orleans district is used. This curve was used because it is reasonable to assume that mobile homes across the nation would face similar depth-damage functions from various heights of fresh water flooding and would also have similar CSVRs.

A weighted average depth-damage curve was developed to represent the makeup of vehicle ownership in the Walla Walla area based on EGM 09-04, Generic Depth-Damage Relationships for Vehicles (USACE, 2009). The vehicle types examined in EGM 09-04 include sedans, pickups, SUVs, sports cars and mini vans. For this study, only sedans, pickups, and SUVs were considered when creating the weighted depth-damage curve because these types are most representative of the automobiles in the Walla Walla area. The percentage of damage to a certain type of vehicle at varying elevations was multiplied by the percentage that vehicle type represented of the total number of vehicles sampled. This process was followed for each vehicle type and the results were totaled, giving a single depth-damage relationship that could be applied to each residence. The same process was also followed to derive the standard deviations of damages at different water depths.

3.2.9 Damage Functions: Non-residential and Infrastructure

The depth-damage functions for non-residential structures and contents were based on the data presented from the draft report *Solicitation of Expert Opinion Depth-Damage Function Calculations for the Benefit-Cost Analysis Tool* (URS Group, 2008). Twenty-one core non-residential structure types were evaluated by a panel of experts from across the United States. The resulting data from the panel included nationally relevant depth-damage functions (DDFs) for use in estimating the value of damages from flooding to commercial, industrial, and public structures.

Uncertainty measures were incorporated into the commercial and public depth-damage functions. For non-residential structures, depth-damage function uncertainties are expressed as a triangular distribution.

3.2.10 Damage Functions: Roads and Railroads

The magnitude of damages (and costs) by flood event were developed based upon an estimate of the types of damages that would occur given the flood depths, durations, and velocities as estimated by recurrence event. Estimated levels of damage were developed from review of historical flood information in the Walla Walla District. The damages were assumed to progress along an increasing cost path that would start with clean-up costs at lower inundation depths and extend toward reconstruction at a maximum for the greatest depths. Based on examination of recent floods in the region, and discussions with governmental employees involved with the cleanup of these floods, it has been assumed that some clean-up work would be required upon any roadway that is inundated. Based on discussions with a regional floodplain manager, road damages included cleanup of mud and cobbles even in areas where road inundation was very minor (less than ½ foot). Built on this reference point, it was determined that the depth damage function should reflect that minor damage may occur for any depth of flooding. This function was input into HEC-FDA such that damage is allowed to begin once depth of flooding is above zero feet, allowing HEC-FDA to interpolate damages for minor depths of flooding prior to the depth that would initiate a full clean-up effort.

Next, additional key points along the damage function were identified in order to create a step function to move through the identified levels of damage and estimate the points where the next level of construction effort is required. For example, the damage function assumes that at 2-feet of inundation the full level of effort for clean-up work would be required. Therefore, there is 10 percent damage at this depth. The next step is at the 5-foot depth. This is where it is assumed that the full cost of maintenance would be required, and therefore the 28 percent damage is shown. The damage percentages located between these two steps is calculated via simple linear interpolation. The damage function continues through this same manner to include the resurfacing costs at 7-feet of inundation and to reconstruction at 9-feet. Table 3-5 includes the damage function discussed in this section.

Table 3-5. Roadway Depth-Damage Function

Depth	Damage (%)	Low Damage (%)	High Damage (%)	Standard Deviation (%)
-2.0	0%	0%	0%	0.00%
-1.0	0%	0%	0%	0.00%
0.0	0%	0%	0%	0.00%
0.5	3%	1%	10%	2.15%
1.0	5%	3%	14%	2.68%
1.5	8%	4%	17%	3.35%
2.0	10%	5%	21%	4.03%
2.5	13%	6%	25%	4.70%
3.0	16%	7%	28%	5.32%
3.5	19%	8%	32%	5.88%
4.0	22%	10%	35%	6.18%
4.5	25%	15%	38%	5.83%
5.0	28%	19%	41%	5.41%
5.5	31%	24%	50%	6.65%
6.0	35%	28%	60%	7.93%
6.5	38%	31%	70%	9.55%
7.0	41%	35%	79%	11.18%
7.5	53%	38%	89%	12.78%
8.0	65%	41%	91%	12.54%
8.5	77%	50%	93%	10.73%
9.0	89%	60%	96%	8.90%
9.5	91%	70%	98%	7.08%
10.0	93%	79%	100%	5.20%
10.5	95%	89%	100%	2.82%

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For railroads, the depth-percent damage curves from the 2014 Kansas Citys, Missouri and Kansas Flood Risk Management Final Feasibility Report were used, and compared with other Northwestern Division curves to determine estimated uncertainties. The depth-damage function used in the 2014 Feasibility Study was based on interviews with local railroad officials and were determined to be appropriate since the same major railroads appropriate throughout the continental United States. The depth-damage function for railroad track is shown in Table 3-6.

Table 3-6. Railroad Depth-Damage Function

Depth	Damage	Standard Deviation of Error
-2.0	0.0%	0.0%
-1.0	0.5%	0.0%
0.0	1.0%	1.0%
1.0	3.1%	1.0%
2.0	7.1%	2.0%
3.0	10.0%	2.0%
4.0	15.0%	4.0%
5.0	20.0%	6.0%
6.0	22.0%	6.0%
7.0	24.0%	6.0%
8.0	26.0%	6.0%
9.0	28.0%	6.0%
10.0	30.0%	6.0%
11.0	32.0%	7.0%
12.0	34.0%	7.0%
13.0	36.0%	8.0%
14.0	38.0%	9.0%
15.0	40.0%	11.0%
20.0	42.0%	12.0%
25.0	44.0%	13.0%
30.0	46.0%	14.0%
35.0	48.0%	15.0%

3.2.11 Other Damage Categories

In addition to the analysis of damages to structures, contents, and other physical property, several other relevant damage categories may be evaluated as part of the economic analysis. These additional damage categories may include: road detour and delays, railroad damages, rail detour and delays, emergency costs, crop damages and National Flood Insurance Program (NFIP) administrative cost savings. The preliminary alternatives screening includes damages to structures, contents, and vehicles as well as road damages and emergency costs. Note that the preliminary analysis includes emergency costs only as a percentage of the structure, content,

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and vehicle damages. Further analysis and refinement based on collected data and modeling will be completed on the selected plan during optimization.

3.2.11.1 Emergency Costs and Disaster Relief

Emergency cost savings include a wide range of flood impacts and response/avoidance costs, including emergency services costs, flood fighting costs, avoidance costs, debris cleanup, and damage to other infrastructure items not otherwise included in the damage analysis. Estimates of emergency costs at different magnitude flood events and corresponding damage functions are typically determined based on historical flood fight cost data for the local community or study area. Current estimates of emergency costs are based on previous studies in the Northwestern Division and are set at 10 percent of property damages.

3.2.11.2 Road Detour and Delays

Flooding can temporarily impede traffic by coving roads and bridges. Even the threat of flooding and concern for public safety may make it necessary to close roads and detour traffic. The costs of traffic disruption include 1) the additional operating cost for each vehicle, including depreciation, maintenance, and gasoline per mile of detour; and 2) the traffic delay cost per passenger. Although the city of Walla Walla would experience road and bridge closures during extreme flood events, it is not known if implementation of the flood mitigation alternatives evaluated in this study (levees/floodwalls) would not preclude closure. Thus, in the without and with project conditions there would be closure of these roads during extreme flood events. No transportation benefits were analyzed at this time. If appropriate, this will be conducted post-TSP.

3.2.11.3 National Flood Insurance Program Administration Cost Savings

The Flood Insurance Administration (FIA) expends significant time and effort administering each flood insurance policy under the National Flood Insurance Program Administration (NFIP). The estimated average annual cost of this time and effort is $192 (per Corps Economic Guidance Memo 06-04). It is anticipated that, if left changed, the existing levees will not meet FEMA levee certification requirements in the future. Therefore, the No Action Alternative would result in additional flood insurance premium costs for approximately 1,250 homeowners within the 100-year floodplain. The benefits provided by the TSP could include an additional $240,000 in annual savings for Walla Walla homeowners who would avoid mandatory NFIP coverage in the future. However, the future without project condition hydraulic modeling is still preliminary and these benefits are not included at this time. This analysis will be added post-TSP as appropriate.

3.2.12 Summary of Economic Uncertainties

The valuation of residential and non-residential structures and contents along with vehicle losses were estimated with uncertainty. Structure value uncertainty is captured simply with a standard deviation of 25 percent and assumed to be normally distributed. These assumptions

are based on past studies completed in the Northwestern Division and are considered sufficient for screening alternatives. Content value uncertainties were based on the American River ERR mentioned previously and are also normally distributed. These uncertainty parameters for valuation were imported into the HEC-FDA program.

Several factors contributed to the uncertainty associated with automobile damages. These factors include the average unit value, the number of vehicles per residence assumed, and the evacuation rate. The vehicles per residence (two) is based on 2017 American Community Survey data. It was assumed that the evacuation rate was 50 percent based on previous studies. An average value of an automobile was determined to be $18,000. While uncertainty in these variables was not considered, uncertainty in the percent damage by depth (as reflected in the depth-percent damage curves in EGM 09-04) was taken into account.

Uncertainty in first floor elevation was also included in the model. During the virtual field inventory, first floor (foundation height) estimates were made by visual inspection and assigned to structures in one quarter-foot increments. Averages were applied across structures of similar types and locations. Based on this level of precision and guidance provided by EM 1110-2-1619 it was assumed that 0.5 foot standard deviation would capture the potential uncertainty in this first floor elevation.

The uncertainty associated with the percent damages at specific depths of flooding for automobiles and structures/contents were entered into the HEC-FDA model. Residential structure and content depth-percent damage curves are normally distributed and include standard deviations of percent damages by depth of flooding. Non-residential content depth-percent damage curves are triangularly distributed and include a minimum, most likely, and maximum percent damage by depth of flooding.

3.3 FINAL DATABASE – INVESTMENT AND POPULATION AT RISK

Completion of the tasks discussed above ultimately results in an economic structure inventory. The structure inventory is subsequently used for several purposes, but initially it is the basis for estimates of investment in the study area.

3.3.1 Investment

Investment for the Mill Creek study area is summarized in Table 3-7. The structure inventory includes residential, commercial, and public structures along with the associated content and vehicle values as well as roads and railroads. The total investment in the Mill Creek Study Area (0.1 percent AEP floodplain) is $7.4 billion including near $5.0 billion in residential property.

Table 3-7. Total Investment

Property Type	Mill Creek Study Area
Residential	
Total Structures	13,620
Value – Structures	$2,408,716,158
Value – Contents	$2,281,135,747
Value – Vehicles	$258,090,534
Value – Total	$4,947,942,439
Commercial	
Total Structures	1,030
Value – Structures	$531,472,509
Value – Contents	$727,387,333
Value – Vehicles	$383,178
Value –Total	$1,259,243,020
Public	
Total Structures	185
Value – Structures	$328,816,073
Value – Contents	$131,770,731
Value –Total	$460,586,804
Roads	
Miles	1,069.25
Value	$684,246,196
Railroads	
Miles	180.76
Value	$46,968,348
Totals	
Total - Structures	14,835
Total – Road and Railroad Miles	1,250.01
Total – Value	$7,398,986,806

Note: FY20 price level

3.3.2 Population at Risk

Two HEC-LifeSim models were developed in the Mill Creek study area by the Modeling, Mapping and Consequences (MMC) Production Center to estimate potential life loss for various levee failure scenarios. Data and results from these models, the Mill Creek Left Bank and Mill Creek Right Bank levees, were utilized as no significant changes in their structure inventories and hydraulic data are expected between the finalization of the Mill Creek Levee System reports in 2016 and current existing conditions. A breach location near the largest population center along the levee system was considered to evaluate the potential highest consequences.

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Population at risk (PAR) is the portion of the population living, working, or otherwise temporarily in the study area flood plain. These persons are potentially at risk in the event of flooding and are detailed in Table 3-8 with estimates disaggregated by modeled levee failure events.

Table 3-8. Levee Breach Failure Human Impacts

Hydrologic Loading Condition	Structures Inundated	Approximate PAR
Overtopping Breach	1,800	9,100
Overtopping Non-Breach	2,000	9,400
Top of Levee Breach	700	4,000
75% Levee Height Breach	15	40
50% Levee Height Breach	10	35

Life loss estimates for modeled levee failure events are detailed in Table 3-9. The PAR and life loss estimates reported for these scenarios are inclusive of inaccuracies inherent in the information and methods that were used. A consistent approach was used to estimate consequences for all failure and overtopping scenarios. For life loss, minimal warning time represents a warning issuance range from 2 hours prior to breach initiation to 30 minutes after breach initiation, and ample warning time represents a warning issuance of 24 hours prior to breach initiation. Table 3-9 shows average values which were zero under all scenarios. However, Monte Carlo simulation with many iterations that represent a range of uncertainty in evacuation effectiveness assumptions was performed and the individual iterations did show up to four fatalities for some scenarios.

Table 3-9. Levee Breach Failure Life Loss Estimates

Hydrologic Loading Condition	Minimum Warning Day	Minimum Warning Night	Ample Warning Day	Ample Warning Night
Overtopping Breach	0	0	0	0
Overtopping Non-Breach	0	0	0	0
Top of Levee Breach	0	0	0	0
75% Levee Height Breach	0	0	0	0
50% Levee Height Breach	0	0	0	0

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SECTION 4 - DAMAGE ANALYSIS MODELING

4.1 MODELING FOR MILL CREEK

4.1.1 Basic Modeling

The comprehensive structure inventory for the study area discussed above in section 3, including elevations, values, and depth-damage functions for each property, accompanied by uncertainty factors, and the set of water surface profiles were entered into the HEC-FDA risk analysis program for damage computations. Damages in this analysis consist of physical inundation damages to commercial, industrial, residential, and public structures and their contents and vehicles. Without-project and with-project water surface profiles were prepared for eight flood events. This analysis uses one set of profiles for all without-project conditions: existing, base year, and future. The sets of profiles were prepared for each of the failure modes and structural alternatives.

4.1.2 Exceedance Probability-Discharge Functions

For a flood or storm event with a given probability of occurrence, there is uncertainty regarding what the resulting discharge will be at a specific location along the stream or river. The reliability of frequency-discharge estimates is directly linked to the historical record of stream gauge data available. In cases where records are small or incomplete, the associated uncertainty increases. To address this uncertainty, an analytical or graphical method is typically used to determine statistical distributions of discharge for a range of probabilities at locations throughout the floodplain.

For this study, exceedance probability-discharge uncertainty has been estimated based upon an equivalent record length of 78 years for all tributaries and reaches based on input from the hydrologic engineer and EM 1110-2-1619. More information can be found in the Hydraulics and Hydrology (H&H) Appendix.

4.1.3 Stage-Discharge Functions

For a given level of storm water discharge, there is uncertainty regarding what the resulting water surface elevation will be at a given location. Factors contributing to this uncertainty include bed forms, water temperatures, debris or other obstructions, unsteady flow effects, variation in hydraulic roughness with season, sediment transport, channel scour or deposition, changes in channel shape during or as a result of flood events, as well as other factors. To address this uncertainty, standard deviation estimates are developed for stages associated with a range of discharges at locations throughout the floodplain.

Following traditional procedures presented in EM 1110-2-1619, standard deviations of between 1.1 and 1.3 feet were computed for the identified failure locations in the Mill Creek study area. Additionally, each failure location had an identified stage where error becomes constant. Both parameters are detailed in Table 4-1.

Table 4-1. Constant Error Stage by Failure Mode

Index Point (Failure Location)	Stage Where Error Becomes Constant (feet)	Stage Standard Deviation
Pipe Column	956.12	1.1
Ceiling Cover	956.12	1.1
Otis Street Blockage	984.39	1.1
Tausick Way	1,140.74	1.3
Yellowhawk	1,177.27	1.1

4.1.4 Levee Features

Hydraulic engineers were consulted to determine the appropriate top of levee stage to apply to each of these failure locations. Assigning levees to damage reaches truncates the stage-damage curve computed by the model and excludes damages from the annualized calculation that are occurring at stages below the top of levee stage. These levees are included in the existing conditions modeling. Table 4-2 below provides the leveed reaches and their top of levee stages based on their event flow level of protection.

Table 4-2. Levee Features by Failure Mode

Index Point (Failure Location)	Top of Levee (Stage)
Pipe Column	961.43
Ceiling Cover	961.43
Otis Street Blockage	990.09
Tausick Way	1144.89
Yellowhawk	1181.81

A geotechnical levee fragility curve shows the probabilities of failure at different water surface elevations against a levee. Fragility curves are a main component of the economic modeling and in determining the performance of a project, which is often described in terms of annual exceedance probability (AEP) or the chance of flooding in any given year.

For this analysis, three sets of geotechnical levee fragility curves were used in the economic analysis, one set for each index point located on a levee reach, with each set including a without-project and with project curve. Details about the development of the geotechnical fragility curves can be found in the Geotechnical Appendix. The geotechnical data and curves used in the economic analysis that can be found in the Mill Creek GI HEC-FDA models are shown in Table 4-3.

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Table 4-3. Geotechnical Fragility Curves

Event Flow (cfs)	Pipe Column P(f)	Ceiling Cover P(f)	Otis Street Blockage P(f)	Tausick Way P(f)	Yellowhawk P(f)
0	0.00000	0.00000	0.00014	0.00000	0.00000
3,000	0.03310	0.03501	0.02370	0.00000	0.00000
3,500	0.09847	0.03620	0.08118	0.19220	0.00000
4,300	0.20306	0.03810	0.17301	0.26760	0.00000
4,500	0.22921	0.03857	0.19597	0.31182	0.00000
5,400	0.38030	0.04066	0.20000	0.51079	0.00000
5,500	N/A	N/A	N/A	0.53290	0.00000
7,000	N/A	N/A	N/A	N/A	0.00000
9,194	N/A	N/A	N/A	N/A	0.00200

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SECTION 5 - EXISTING AND FUTURE WITHOUT-PROJECT CONDITIONS

As discussed above, there is no distinction in this analysis between existing, base year, and future conditions. Water surface profiles and other hydrologic/hydraulic data are considered stable over the period of analysis, as is the economic structure inventory. The results summarized in this section therefore will represent existing conditions as well as future without-project conditions.

5.1 Expected Annual Damages (EAD)

The without-project conditions EAD calculated by the HEC-FDA model are summarized in Table 5-1. As you can see from Table 5-1, the pipe column failure mode has the highest expected annual damages with just under $1.4 million. The next three failure modes in terms of highest expected annual damages are Ceiling Cover ($1,003,480), Otis Street Blockage ($928,460), and Tausick Way ($918,900). The Yellowhawk failure mode exhibits the least amount of expected annual damages with $757,610. This is due to the extremely low probability of failure, 0.2 percent at top of protection, and the nature of the inundation under a failure scenario.

Table 5-1. Without-Project Condition EAD

Index Point (Failure Mode)	Commercial	Public	Rail	Residential	Road	Emergency	Total
Pipe Column	377.09	23.49	17.38	295.53	471.51	118.50	1,303.500
Ceiling Cover	275.89	19.66	14.07	247.06	355.57	91.23	1,003.48
Otis Street Blockage	263.99	23.26	7.51	248.75	300.54	84.41	928.46
Tausick Way	248.27	18.11	7.75	237.86	323.27	83.54	918.90
Yellowhawk	187.69	18.16	4.84	213.75	264.30	68.87	757.61

Note: FY20 price level; 2.75 percent interest rate; values shown in thousands

5.2 AEP EVENT DAMAGES

The HEC-FDA program also produces estimates of damages in selected events, and two common reference events are the one percent and 0.2 percent flood events. Damages in these two events and others, as calculated within the HEC-FDA program, are presented by failure mode in Table 5-2. It should be noted that these damages were computed without risk and uncertainty and are likely much higher. However, when HEC-FDA was run with risk and uncertainty it was reporting damages at higher AEPs that were not occurring.

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Table 5-2. Annual Exceedance Probability vs. Damage (Without Condition)

AEP	Pipe Column	Ceiling Cover	Otis Street Blockage	Tausick Way	Yellowhawk
50.00%	552.25	552.25	62.28	0.00	0.00
20.00%	4,046.47	4,046.47	113.86	0.00	0.00
10.00%	4,065.11	4,065.11	113.96	0.00	0.00
4.00%	1,4052.57	1,4052.57	8,574.75	0.00	0.00
2.00%	28,411.68	28,411.68	32,811.68	0.00	0.00
1.00%	30,878.72	30,878.72	36,305.39	0.00	0.00
0.50%	34,176.27	34,176.27	39,642.30	0.00	0.00
0.20%	114,028.83	114,028.83	94,370.83	82,315.58	78,013.24
0.10%	144,448.92	144,448.92	148,163.91	154,318.40	147,332.24

Note: in $1,000s, FY20 price level, 50-year period of analysis

5.3 ENGINEERING PERFORMANCE

An additional result of the risk analysis is a set of statistics characterizing project performance or assurance – the probability that a project will successfully contain flood events of varying magnitudes. There are three main assurance outputs. Target stage annual AEP is the probability of a damaging flood occurring in any given year. A mean and median AEP associated with the target stage are calculated with the median determined by model inputs for the discharge-probability and stage-discharge functions and the mean computed in the Monte Carlo simulation. A second output is long-term risk; the probability that the target stage will be exceeded over periods of 10, 30, and 50 years. The third output is conditional non-exceedance probability (assurance). Assurance is an estimate of the probability of containing certain specified flood events of interest within the target stage, should that event occur.

For each of the failure modes, the target stage is the top of levee elevation. That information is available in the levee features section. The AEP and long-term risk statistics for each failure mode under the without-project condition are listed in Table 5-3 below. From a project performance standpoint, the Tausick Way failure mode performs the worst with an expected annual exceedance probability of 9.6 percent and a 95.2 percent chance of experiencing a damaging flood over a 30-year time period.

Table 5-3. Without Project Exceedance Probability and Long Term Risk

Failure Mode	Target Stage	Median AEP	Expected AEP	Long Term Risk (10 years)	Long Term Risk (30 years)	Long Term Risk (50 years)
Pipe Column	963.87	0.0250	0.0276	0.2443	0.5684	0.7535
Ceiling Cover	963.87	0.0236	0.0234	0.2105	0.5079	0.6933
Otis Street Blockage	991.27	0.0172	0.0181	0.1670	0.4219	0.5988
Tausick Way	1144.89	0.0921	0.0960	0.6354	0.9515	0.9936
Yellowhawk	1181.81	0.0025	0.0038	0.0369	0.1068	0.1715

The assurance statistics for each reach under the without-project condition are presented in Table 5-4. Again, the Tausick Way failure mode presents the worst assurance with only a 71 percent chance of providing protection at the 1 percent AEP (100-year).

Table 5-4. Without Project Assurance by Event

Failure Mode	10%	4%	2%	1%	0.40%	0.20%
Pipe Column	0.9701	0.9242	0.8918	0.8780	0.5203	0.3337
Ceiling Cover	0.9722	0.9668	0.9644	0.9638	0.7225	0.4799
Otis Street Blockage	0.9834	0.9582	0.9182	0.9046	0.5713	0.0001
Tausick Way	0.8815	0.8075	0.7295	0.7120	0.4431	0.0076
Yellowhawk	0.9997	0.9907	0.9728	0.9645	0.8074	0.1876

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SECTION 6 - ALTERNATIVES SCREENING

6.1 OVERVIEW OF EVALUATION PROCEDURES

Economic costs and benefits resulting from a project are evaluated in terms of their impacts on national wealth, without regard to where in the United States the impacts may occur. National Economic Development (NED) benefits must result directly from a project and must represent net increases in the economic value of goods and services to the national economy, not simply to a locality. For example, if a flood interrupts auto production at a plant in one community, that community suffers a loss. But if the affected company replaces the interrupted production at another plant in another city, the community's loss does not represent a net loss to the national economy, and the prevention of such a loss cannot be claimed as a NED benefit.

NED costs represent the costs of diverting resources from other uses in implementing the project, as well as the costs of uncompensated economic losses resulting from detrimental effects of the project. NED benefits, the benefit-cost ratio, and the net NED benefits are calculated during the evaluation process. Net benefits represent the amount by which the NED benefits exceed NED costs, thereby defining the plan's contribution to the nation's economic output. The plan with the highest net benefits is considered the recommended plan, assuming technical feasibility, environmental soundness, and public acceptability. Note that the plan with highest net benefits is not necessarily the plan with the highest benefit-cost ratio. The benefit-cost ratio helps identify which plans have likely economic feasibility and can be carried forward for further analysis, but is not decisive in identifying the NED plan from among those plans that are economically feasible.

To determine the economic justification of the array of alternatives, each alternative was entered into the HEC-FDA risk analysis model. The Monte Carlo analysis in HEC-FDA was then employed to determine residual damages – i.e., damages that would continue to occur in the with-project condition even with implementation of that alternative. The residual damages that would continue to occur in the with-project condition were expressed as expected annual damages that account for both the base year condition and the discounted present-worth of the future year condition. The difference between the without condition EAD and the residual EAD for each alternative represents the damages reduced or benefits for the alternative. The alternatives analysis involved no modifications to the existing condition economic structure inventory and occupancy type data.

Screening benefits in this analysis were based on physical inundation reduction to homes, businesses, public facilities, roads, and railroads. The alternatives for each potential failure mode were modeled in the hydrologic and hydraulic models to develop stand-alone estimates that were evaluated in the economic screening analysis.

6.2 WITH-PROJECT ALTERNATIVES ANALYSIS

Without-project expected annual damages were computed at five representative index points (based on failure mode) throughout the study area. The PDT selected these index points, which are based on the main flood sources, in order to be able to reasonably characterize the flood risk associated within the Mill Creek watershed by accounting for the multiple sources of flooding in the basin.

Similarly, with-project damages reduced (benefits) associated with various project alternatives were also computed at each representative index point for each basin. If the flood risk in a basin (or any other consequence area) could be attributed to one and only one flood source, then the total benefits computed at an index point along a particular flood source would represent the benefits of building a project on that flood source. However, this is not the case for the Mill Creek study area since flood risk in the watershed comes from more than one source. Under this scenario, benefits were computed first at each index point (source), and then estimated for the whole basin by comparing the risk at each index point and using the highest EAD/residual EAD.

6.3 DESCRIPTION OF ALTERNATIVES

Eight alternatives were analyzed, including the No Action Alternative. The No Action Alternative in this study is the same as the future without project conditions. The No Action Alternative sets the baseline from which other alternative are compared. No Action does not mean there would be no impacts from this alternative. The eight initial alternatives are shown in Table 6-1.

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Table 6-1. Screening Criteria Summary

Alternative		Complete	Effective	Efficient	Acceptable
Alternative 1	No Action Plan	Yes	Yes	Yes	Yes
Alternative 2	Concrete Channel Rehabilitation	Yes	No	Yes	Yes
Alternative 3	Levee Raise: Moderate	Yes	No	Yes	Yes
Alternative 4	Levee Raise: Small	Yes	No	Yes	Yes
Alternative 5	Modify Project Operations	Yes	No	Yes	Yes
Alternative 6	Buyout/Acquisition	No	No	No	No
Alternative 7	Modify Project Operations Levee Raise: Small Channel Rehabilitation Buyout/Acquisition	Yes	Yes	Yes	Yes
Alternative 8	Modify Project Operations Levee Raise: Moderate Channel Rehabilitation Buyout/Acquisition	Yes	Yes	Yes	Yes

6.3.1 Screened-Out Alternatives

An initial screening based on the criteria shown in Table 6-1 (completeness, effectiveness, efficiency, and acceptability) ruled out five standalone alternatives. Summary descriptions for each of these alternatives are presented below:

- Alternative 2 improves the existing concrete channel in-place. This alternative was eliminated from consideration as a standalone alternative because it does not effectively address the planning objectives. Rehabilitating the concrete channel would increase the reliability of the Project, but not the capacity. There would be no increased storage capacity in Bennington Lake, and the levees would still be the limiting factor in the amount of floodwater that could be conveyed through the channel. However, this alternative was carried forward as part of combined alternatives.

- Alternative 3 is a moderate levee raise. This was eliminated from consideration as a standalone alternative because it does not effectively address the planning objectives. A moderate levee raise would slightly increase the capacity and performance of the Project, but would not increase reliability. A moderate levee raise would pass an additional 500 cfs through the system during each flood event without addressing any structural degradation of adjacent concrete structures, which would increase the likelihood of failure because the reliability issues in the channel would not be addressed. However, this alternative was carried forward as part of combined alternatives.

- Alternative 4 is small levee raise of up to 1.5 feet throughout the Project. This was eliminated from consideration as a standalone alternative because it does not completely

address the planning objectives. A small levee raise would slightly increase the capacity and performance of the Project, but would not increase the reliability of the Project. A small levee raise would not be effective because the channel conveyance capacity would only increase by 200 cfs, which is still well below the capacity of the concrete channel. However, this alternative was carried forward as part of combined alternatives.

- Alternative 5 modifies the existing project operations through a change in the diversion trigger to 1,700 cfs. This was eliminated from consideration as a standalone alternative because it does not completely address the planning objectives. An operational change would increase capacity and performance, but not Project reliability. An operational change would not be effective because larger volumes of floodwater would be passed through the concrete channel section during each flood event without having reinforced the concrete, which would increase the likelihood of failure because the reliability issues in the channel would not be addressed. However, this alternative was carried forward as part of combined alternatives.

- Alternative 6 would buy existing structures and land and inhibit future development in undeveloped floodplain. This was eliminated as a standalone alternative because it does not meet any of the screening criteria. This measure could be added to any alternative, as necessary, to offset any increased flood frequency or potential damages from modifications to the existing project.

6.3.2 Final Array of Alternatives

Based on the results from the initial screening, the final array of alternatives includes the No Action Alternative, Alternative 7, and Alternative 8. Summary descriptions for the two combined alternatives are presented below:

- Alternative 7 includes a combination of channel rehabilitation and a small levee raise with operational changes and acquisition of flowage easements.

- Alternative 8 includes a combination of channel rehabilitation and a moderate levee with operational changes and acquisition of flowage easements.

6.4 WITH-PROJECT RESULTS: RESIDUAL EAD AND BENEFITS BY INDEX POINT

The following tables show the without-project EAD and with-project residual EAD results computed in HEC-FDA for each index point/breach location. The benefits shown for each alternative in each table are the damages reduced at a respective index point/breach location, and represent the benefits to the basin if improvements were to occur on the source of flooding where the index point is located and if there were no other sources of flood risk.

For example, in Table 6-2, the benefits of Alternative 8 are approximately $790,000. All of these benefits could be claimed if improvements to the Mill Creek channel were made in conjunction with a moderate levee raise, and if there were no other sources of flood risk.

While the first condition (improvements to the channel and levee raise) would be met under this scenario, the second condition under this scenario has not yet been met –there is still flood risk from other water sources. Since there is still flood risk from other sources, the full $790,000 in benefits cannot be claimed for the entire basin. (In the next section, the benefits for the basin as a whole are estimated by considering all sources of flood risk.)

Table 6-2 through Table 6-6 display both the without-project and with-project data per index point. The first set is associated with outputs derived from channel improvements, along with a small levee raise, made under Alternative 7; the second set is associated with outputs derived from channel improvements, along with a moderate levee raise made under Alternative 8.

Table 6-2. Without-Project EAD and With-Project EAD (Pipe Column)

Damage Category	Without EAD	Alternative 7 Residual EAD	Alternative 7 Benefits	Alternative 8 Residual EAD	Alternative 8 Benefits
Commercial	377.09	171.96	205.13	163.93	213.16
Public	23.49	15.23	8.26	13.39	10.10
Railroads	17.38	3.71	13.67	2.85	14.53
Residential	295.53	180.21	115.32	159.57	135.96
Roads	471.51	156.33	315.18	127.40	344.11
Emergency	118.50	52.74	65.76	46.71	71.79
Total	1,303.50	580.18	723.32	513.85	789.65

Note: values in $1,000s, FY 20 price level, 50-year period of analysis

Table 6-3. Without-Project EAD and With-Project EAD (Ceiling Cover)

Damage Category	Without EAD	Alternative 7 Residual EAD	Alternative 7 Benefits	Alternative 8 Residual EAD	Alternative 8 Benefits
Commercial	275.89	171.96	103.93	163.93	111.96
Public	19.66	15.23	4.43	13.39	6.27
Railroads	14.07	3.71	10.36	2.85	11.22
Residential	247.06	180.21	66.85	159.57	87.49
Roads	355.57	156.33	199.24	127.40	228.17
Emergency	91.23	52.74	38.48	46.71	44.51
Total	1,003.48	580.18	423.29	513.85	489.62

Note: values in $1,000s, FY 20 price level, 50-year period of analysis

Table 6-4. Without-Project EAD and With-Project EAD (Otis Street Blockage)

Damage Category	Without EAD	Alternative 7 Residual EAD	Alternative 7 Benefits	Alternative 8 Residual EAD	Alternative 8 Benefits
Commercial	263.99	197.29	66.70	225.31	38.68
Public	23.26	19.50	3.76	20.61	2.65
Railroads	7.51	5.58	1.93	6.15	1.36
Residential	248.75	210.00	38.75	220.79	27.96
Roads	300.54	230.69	69.85	260.63	39.91
Emergency	84.41	66.31	18.10	73.35	11.06
Total	928.46	729.37	199.09	806.84	121.62

Note: values in $1,000s, FY 20 price level, 50-year period of analysis

Table 6-5. Without-Project EAD and With-Project EAD (Tausick Way)

Damage Category	Without EAD	Alternative 7 Residual EAD	Alternative 7 Benefits	Alternative 8 Residual EAD	Alternative 8 Benefits
Commercial	248.27	168.27	80.00	166.03	82.24
Public	18.11	14.54	3.57	14.30	3.81
Railroads	7.75	4.62	3.13	4.64	3.11
Residential	237.86	194.31	43.55	185.57	52.29
Roads	323.37	221.49	101.88	220.61	102.76
Emergency	83.54	60.32	23.21	59.12	24.42
Total	918.90	663.55	255.34	650.27	268.63

Note: values in $1,000s, FY 20 price level, 50-year period of analysis

Table 6-6. Without-Project EAD and With-Project EAD (Yellowhawk)

Damage Category	Without EAD	Alternative 7 Residual EAD	Alternative 7 Benefits	Alternative 8 Residual EAD	Alternative 8 Benefits
Commercial	187.69	191.34	-3.65	175.25	12.44
Public	18.16	18.21	-0.05	17.16	1.00
Railroads	4.84	4.98	-0.14	4.39	0.45
Residential	213.75	219.64	-5.89	196.14	17.61
Roads	264.30	266.82	-2.52	238.47	25.83
Emergency	68.87	70.10	-1.22	63.14	5.73
Total	757.61	771.09	-13.48	694.55	63.06

Note: values in $1,000s, FY 20 price level, 50-year period of analysis

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6.5 RANGE OF BENEFITS BY INDEX POINT AND ALTERNATIVE

The following tables present ranges of benefits for each alternative and at each index point. HEC-FDA computes damages reduced (benefits) at specific probabilities (25 percent, 50 percent, and 75 percent); the intersection of the probability and the dollar value in the table can be read as, "There is an X chance that damages reduced (benefits) exceeds Y." The benefits in these tables provide a broader picture of the possible range in benefits that may be realized considering all of the hydrologic, hydraulic, geotechnical, and economic uncertainty. It should be noted that these values do not include emergency costs as these were computed outside of HEC-FDA and determining probabilistic estimates was not possible. However, they would add approximately 10 percent to the values.

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Table 6-7. Range of Benefits (Pipe Column)

Alternative	Without-Project EAD	With-Project EAD	Expected Benefits	Probability Benefits Exceed 75%	Probability Benefits Exceed 50%	Probability Benefits Exceed 25%
No Action	1,185.00					
Alternative 7	1,185.00	527.43	657.57	238.47	380.06	826.46
Alternative 8	1,185.00	467.14	717.86	251.20	765.70	929.99

Note: values in $1,000s, FY20 price level, 50-year period of analysis

Table 6-8. Range of Benefits (Ceiling Cover)

Alternative	Without-Project EAD	With-Project EAD	Expected Benefits	Probability Benefits Exceed 75%	Probability Benefits Exceed 50%	Probability Benefits Exceed 25%
No Action	912.25					
Alternative 7	912.25	527.43	384.82	136.79	223.90	570.04
Alternative 8	912.25	467.14	445.11	149.53	609.54	673.57

Note: values in $1,000s, FY20 price level, 50-year period of analysis

Table 6-9. Range of Benefits (Otis Street Blockage)

Alternative	Without-Project EAD	With-Project EAD	Expected Benefits	Probability Benefits Exceed 75%	Probability Benefits Exceed 50%	Probability Benefits Exceed 25%
No Action	844.06					
Alternative 7	844.06	663.06	181.00	73.83	129.38	257.02
Alternative 8	844.06	733.49	110.57	114.26	174.26	311.84

Note: values in $1,000s, FY20 price level, 50-year period of analysis

Table 6-10. Range of Benefits (Tausick Way)

Alternative	Without-Project EAD	With-Project EAD	Expected Benefits	Probability Benefits Exceed 75%	Probability Benefits Exceed 50%	Probability Benefits Exceed 25%
No Action	835.26					
Alternative 7	835.26	603.23	232.03	73.10	72.23	108.64
Alternative 8	835.26	591.15	244.11	126.95	140.40	179.66

Note: values in $1,000s, FY20 price level, 50-year period of analysis

Table 6-11. Range of Benefits (Yellowhawk)

Alternative	Without-Project EAD	With-Project EAD	Expected Benefits	Probability Benefits Exceed 75%	Probability Benefits Exceed 50%	Probability Benefits Exceed 25%
No Action	688.74					
Alternative 7	688.74	631.42	57.32	71.15	67.25	147.04
Alternative 8	688.74	700.99	-12.25	5.97	-13.79	24.27

Note: values in $1,000s, FY20 price level, 50-year period of analysis

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6.6 WITH-PROJECT RESULTS: BENEFITS BY ALTERNATIVE

Table 6-12 below displays the benefits of each alternative from the perspective of looking at the Mill Creek study area as one complete flood risk management system. The benefit values in these tables reflect improvements made to each source of flood risk within the watershed. For example, flood risk management improvements are implemented to reduce flood risk associated with the Pipe Column, Ceiling Cover, Otis Street Blockage, Tausick Way, and Yellowhawk failure modes. This table reflects benefits that would be realized in the basin (i.e., in a single consequence area) by thinking of the flood problem from a broader system perspective rather than from just individual, isolated (index points/breach locations) sources of flood risk.

As the results in Table 6-12 indicate, when looking at the Mill Creek watershed as one system, the benefits of both alternatives are similar. The rationale for this outcome is that under both alternatives, all improvements are assumed to be made with the only difference being the height of the levee. The residual risk is associated with the "weakest link" in the system after all improvements are made, which under Alternative 7 turns out to be the Yellowhawk index point. For Alternative 8, the highest residual risk is associated with the Otis Street Blockage. The residual EADs at these locations are approximately $771,000 and $807,000 for Alternative 7 and Alternative 8, respectively.

Table 6-12. Average Annual Benefits by Alternative

Alternative	Without-Project EAD	With-Project EAD	Average Annual Benefits
No Action	1,303.50		
Alternative 7	1,303.50	771.09[1]	532.41
Alternative 8	1,303.50	806.84[2]	496.66

Note: values in $1,000s, FY20 price level, 50-year period of analysis
[1] Residual EAD from Yellowhawk
[2] Residual EAD from Otis Street Blockage

If looked at from a single index point/reach perspective, residual risk in terms of consequences and chance of flooding differs across index points/breach locations. This can be seen in Table 6-2 to Table 6-6 above for consequences and Table 6-13 to Table 6-15 (in the next section) for chance of flooding.

6.7 WITH-PROJECT PERFORMANCE RESULTS: AEP, LONG-TERM RISK, AND ASSURANCE

Table 6-13 to Table 6-15 present the performance statistics under both without-project and with-project conditions for each index point and alternative.

The AEP values under with-project conditions indicate that both alternatives provide significant risk reduction in terms of the chance of flooding in any given year. For example, at the Pipe Column index point, the without-project AEP is about 1 in 36. With improvements, flood risk as

estimated at Pipe Column is reduced to about a 1 in 588 for Alternative 7 and 1 in 769 for Alternative 8.

The long-term risk statistics indicate that the chance of flooding over specified time periods is also reduced. For example, at Tausick Way the chance of flooding over a 10-year and 30-year period improves significantly with a project in place, going from a 64 percent and 95 percent chance for a 10-year and 30-year period without a project, respectively, to a 7 percent and 17-19 percent chance with a project in place.

The assurance results describe the chance a specified flow event would be contained within the channels of a water source (at a specific index point location). For example, for Pipe Column the chance of containing the 0.4 percent flow event under the without-project condition is about 52 percent. With improvements made, the chance of containing the 0.4 percent flow event increases to about 98 and 99 percent for Alternative 7 and Alternative 8, respectively.

Table 6-13. AEP – Without-Project and With-Project Conditions

Failure Mode	Without Median AEP	Without Expected AEP	Alt 7 Median AEP	Alt 7 Expected AEP	Alt 8 Median AEP	Alt 8 Expected AEP
Pipe Column	0.0250	0.0276	0.0022	0.0017	0.0001	0.0013
Ceiling Cover	0.0236	0.0234	0.0022	0.0017	0.0001	0.0013
Otis Street Blockage	0.0172	0.0181	0.0035	0.0038	0.0028	0.0049
Tausick Way	0.0921	0.0960	0.0036	0.0069	0.0027	0.0064
Yellowhawk	0.0025	0.0038	0.0023	0.0038	0.0021	0.0035

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Table 6-14. Long-Term Risk – Without-Project and With-Project Conditions

Failure Mode	Without 10 Years	Without 30 Years	Without 50 Years	Alt 7 10 Years	Alt 7 30 Years	Alt 7 50 Years	Alt 8 10 Years	Alt 8 30 Years	Alt 8 50 Years
Pipe Column	0.2243	0.5684	0.7535	0.0166	0.0489	0.0802	0.0131	0.0387	0.0636
Ceiling Cover	0.2105	0.5079	0.6933	0.0166	0.0489	0.0802	0.0131	0.0387	0.0636
Otis Street Blockage	0.1670	0.4219	0.5988	0.0375	0.1084	0.1741	0.0476	0.1362	0.2165
Tausick Way	0.6354	0.9515	0.9936	0.0670	0.1878	0.2930	0.0619	0.1746	0.2736
Yellowhawk	0.0369	0.1068	0.1715	0.0375	0.1083	0.1740	0.0342	0.0991	0.1597

Table 6-15. Assurance –With-Project Conditions

Failure Mode	Alt 7 10%	Alt 7 4%	Alt 7 2%	Alt 7 1%	Alt 7 0.4%	Alt 7 0.2%	Alt 8 10%	Alt 8 4%	Alt 8 2%	Alt 8 1%	Alt 8 0.4%	Alt 8 0.2%
Pipe Column	0.9996	0.9998	0.9997	0.9994	0.9795	0.4873	1.0000	0.9986	0.9982	0.9920	0.9920	0.6297
Ceiling Cover	0.9996	0.9998	0.9997	0.9994	0.9795	0.4873	1.0000	0.9986	0.9982	0.9920	0.9920	0.6297
Otis Street Blockage	0.9996	0.9954	0.9931	0.9802	0.8026	0.0043	0.9998	0.9822	0.9645	0.8953	0.8948	0.0489
Tausick Way	0.9992	0.9637	0.9208	0.8803	0.6833	0.0305	0.9996	0.9681	09249	0.8513	0.8510	0.1147
Yellowhawk	0.9997	0.9883	0.9709	0.9543	0.8751	0.2266	0.9997	0.9891	0.9722	0.9434	0.9433	0.3620

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6.8 SCREENING COST ESTIMATES

Costs were prepared by cost engineering staff for each of the alternatives. All costs include interest during construction (IDC) computations which vary depending on the assumed construction length. All screening costs reflect an FY 2020 price level, and the annualized totals reflect the current Federal interest rate of 2.75 percent as well as a 50-year period of analysis. Net annual costs for operation and maintenance, repair, replacement and rehabilitation (OMRR&R) are added to the annualized construction and interest during construction (IDC) costs to determine the total annual costs.

For both Alternative 7 and Alternative 8, modifying project operations is expected to have net cost savings in total OMRR&R expenses when compared to without-project conditions. The Federal portion of the project has an annual budget of $5 million and the reduction in the use of facilities for flood operations is expected to result in $50,000 annual cost savings. Walla Walla County is expected to have an increase in annual OMRR&R expenses as more water will move at higher flows through the channel infrastructure. The baseline OMRR&R expenses for Walla Walla County under without-project conditions is $150,000 annually, and the annual increase in costs attributed to modifying operations is $22,500. Therefore, modification of project operations is expected to have a net annual cost savings of $27,500 for OMRR&R.

Based on information provided by the cost engineering center of expertise, it was determined that the repairs and levee raises would take less than one year to construct. Therefore, a one year construction period with a mid-year payment was used for the IDC calculations. The total construction costs and average annual costs for Alternative 7 and Alternative 8 are shown in Table 6-16 and Table 6-17, respectively.

Table 6-16. Alternative 7 Costs

Cost Component	Construction Cost	Annualized Cost	Net OMRR&R	Average Annual Costs
Rehabilitation of Concrete Channel – Pipe Column Repair	$2,165,240	$81,305	$0	$81,305
Rehabilitation of Concrete Channel – Ceiling Repairs	$3,401,860	$127,741	$0	$127,741
Rehabilitation of Concrete Channel – Wall Tieback Repair	$2,280,740	$85,642	$0	$85,642
Small Levee Raise with Operational Changes and Buyouts/Acquisitions	$2,080,340	$78, 117	($27,500)	$50,617
Total	**$9,928,180**	**$372,805**	**($27,500)**	**$345,305**

Note: FY20 price level, 50-year period of analysis, 2.75% discount rate

Table 6-17. Alternative 8 Costs

Cost Component	Construction Cost	Annualized Cost	Net OMRR&R	Average Annual Costs
Rehabilitation of Concrete Channel – Pipe Column Repair	$2,165,240	$81,305	$0	$81,305
Rehabilitation of Concrete Channel – Ceiling Repairs	$3,401,860	$127,741	$0	$127,741
Rehabilitation of Concrete Channel – Wall Tieback Repair	$2,280,740	$85,642	$0	$85,642
Moderate Levee Raise with Operational Changes and Buyouts/Acquisitions	$4,732,220	$177,696	($27,500)	$150,196
Total	**$12,580,060**	**$472,384**	**($27,500)**	**$444,884**

Note: FY20 price level, 50-year period of analysis, 2.75% discount rate

6.9 NET BENEFIT AND BENEFIT-TO-COST ANALYSES: SINGLE INDEX POINT

When evaluating the feasibility of a specific flood risk management feature, the costs and benefits of the feature can be compared to one another within a narrowly-defined perspective that addresses the flood risk reduction associated with addressing only that single flood risk management feature. This narrow perspective assumes that the benefits (i.e., damage reduction in a consequence area) of a particular feature are fully realized because there are no other sources of risk to be concerned with; that is, once this particular feature is built, the area's flood risk is reduced so significantly that no other measures are necessary.

In reality, the Mill Creek consequence area is vulnerable to multiple sources of flood risk. So while the area may benefit from making improvements to just one source of risk, the area does not realize full benefits until other flood risk management features are built since the area would still be vulnerable from other sources of risk. In this context, consequence areas having multiple sources of risk must rely on various flood risk management improvements located in various geographic locations and implemented over a period of time (phases) that work together. Analyzing a consequence area as one unit having multiple sources of flood risk underlies the rationale for performing incremental net benefit/BCR analyses. An incremental analysis allows for the demonstration, in a logical manner, of the incremental risk reduction that is achieved in the area of concern as various flood risk management components come on line through to the point at which the entire flood risk management system is finally addressed.

Table 6-18 displays the flood risk management features, the sources of risk that the features protect against, and the index point used in the incremental benefit/cost analysis. The incremental analysis is presented in the next section.

Table 6-18. FRM Features and Index Points Used in the Economic Analysis

Feature	Associated Index Point Used to Estimate Net Benefits Provided by Feature
Rehabilitation of Concrete Channel – Pipe Column Repair	Pipe Column
Rehabilitation of Concrete Channel – Ceiling Repairs	Ceiling Repair
Rehabilitation of Concrete Channel – Wall Tieback Repair	Otis Street Blockage
Small Levee Raise with Operational Changes	Tausick Way

6.10 INCREMENTAL NET BENEFIT AND BENEFIT-TO-COST ANALYSES

Incremental net benefit/benefit-to-cost analyses were performed using the major sources of flood risk as the incremental unit. The cost information presented in Table 6-16 and Table 6-17 was used to perform the analyses, which are presented in Table 6-19 and Table 6-20 below.

Addressing in tandem all sources of flood risk as part of an overall system is necessary in order to significantly reduce risk to the city of Walla Walla. Since concrete channels and levees run through the city, until all sources of risk are addressed Walla Walla would still face a relatively significant chance of flooding and incur catastrophic consequences (damages and possible loss of life) should flooding to the area take place. Table 6-19 and Table 6-20 show how an alternative can be broken down into increments in order to attribute benefits to specific features of an alternative and to show how each feature of the Mill Creek FRM system works as one unit – with each feature progressively reducing residual risk to the area as they come on line. The analyses presented in Table 6-19 to Table 6-21 is intended to show how parts of the system work together, how residual risk is incrementally reduced as weak links in the system are strengthened, and how the alternatives differ from one another in terms of incremental net benefits.

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Table 6-19. Incremental Net Benefit and Benefit-to-Cost Analyses for Alternative 7

Increment	Without Project EAD / Residual EAD	Incremental Average Annual Benefits	Cumulative Average Annual Benefits	Incremental Average Annual Costs	Cumulative Average Annual Costs	Incremental Net Benefits	Cumulative Net Benefits	Incremental Benefit-to-Cost Ratio	Cumulative Benefit-to-Cost Ratio
0 – No Action	1,303.50	0.00	0.00	0.00	0.00	0.00	0.00	N/A	N/A
1 – Pipe Column Repair	1,003.48	300.03	300.03	81.31	81.31	218.72	218.72	3.69	3.69
2 – Ceiling Repair	928.46	75.02	375.05	127.74	209.05	-52.72	166.00	0.59	1.79
3 – Wall Tieback Repair	918.90	9.56	384.60	85.64	294.69	-76.08	89.92	0.11	1.31
4 – Small Levee Raise	771.09	147.81	532.41	50.62	345.31	97.19	187.11	2.92	1.54

Note: FY20 price level, 50-year period of analysis, 2.75% discount rate

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Table 6-20. Incremental Net Benefit and Benefit-to-Cost Analyses for Alternative 8

Increment	Without Project EAD / Residual EAD	Incremental Average Annual Benefits	Cumulative Average Annual Benefits	Incremental Average Annual Costs	Cumulative Average Annual Costs	Incremental Net Benefits	Cumulative Net Benefits	Incremental Benefit-to-Cost Ratio	Cumulative Benefit-to-Cost Ratio
0 – No Action	1,303.50	0.00	0.00	0.00	0.00	0.00	0.00	N/A	N/A
1 – Pipe Column Repair	1,003.48	300.03	300.03	81.31	81.31	218.72	218.72	3.69	3.69
2 – Ceiling Repair	928.46	75.02	375.05	127.74	209.05	-52.72	166.00	0.59	1.79
3 – Wall Tieback Repair	918.90	9.56	384.60	85.64	294.69	-76.08	89.92	0.11	1.31
4 – Moderate Levee Raise	806.84	112.06	496.66	150.20	444.88	-38.14	51.78	0.75	1.11

Note: Value in $1,000s, FY20 price level, 50-year period of analysis, 2.75% discount rate

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The increments, as displayed in Table 6-19 and Table 6-20, were determined by assessing the without-project and with-project HEC-FDA AEP and EAD results. The first increment, under both alternatives, would be to repair the pipe column since the economic HEC-FDA modeling indicates that this is the weakest point of the system in terms of the chance and consequences of flooding. Following the pipe column improvements, the next increment, under both alternatives, would be to address the ceiling cover repairs. Once these improvements are made, the next increment, under both alternatives, would be to address the wall tieback repair at Otis Street. The final increment would be to address the levees along Tausick Way with either a small levee raise (Alternative 7) or a moderate levee raise (Alternative 8). Both levee raises would lead to the implementation of the operational changes.

6.11 IDENTIFICATION OF THE TENTATIVELY SELECTED PLAN (TSP)

Based on the results of the screening of measures and alternatives, and an analysis of costs and benefits for the final array of alternatives, the TSP is Alternative 7 with potential increases to levee height based on future changes to the overall net benefits. The TSP is also the plan that maximizes the annual net benefit contribution to NED consistent with protecting the Nation's environment. The TSP has a benefit cost ratio of 1.54 and annual net benefits of $187,106.

Table 6-21. Net Benefit and Benefit-to-Cost Analyses by Alternative

Alternative	Average Annual Benefits	Average Annual Costs	Net Benefits	Benefit-to-Cost Ratio
Alternative 7	$532,411	$345,305	$187,106	1.54
Alternative 8	$496,661	$444,884	$51,777	1.12

Note: FY20 price level, 50-year period of analysis, 2.75% discount rate

Alternative 7 is the most complete, effective, efficient, and acceptable alternative to meet the planning objectives. In summary, Alternative 7 accomplishes the following:

- Improves the system's capacity by increasing the levee size along Mill Creek so the channel can convey higher flows.
- Improves the reliability of the Project by rehabilitating and reinforcing the concrete channel through downtown Walla Walla.
- Reduces life cycle costs of the MCFCP by addressing existing vulnerabilities and lowering future overall OMRR&R costs.
- Increases performance of the system by modifying project operations.

The plan formulation process used the best available information at this phase of the study to identify the TSP. However, during the final phase of this feasibility study, additional analyses were completed to refine the TSP's design, costs, and benefits.

6.12 INDUCED DAMAGES

The recommended plan would increase the maximum discharge through the system from the current design flow of 3,500 cfs to 3,700 cfs. This would provide higher flood risk reduction to Walla Walla, but would increase the amount of flood damages downstream of the MCFCP during large flood events.

Existing operation of the MCFCP includes initial diversion of flood flows into Bennington Lake beginning at a flow of 1,400 cfs. Operational changes would associated with the recommended plan would increase this initial diversion flow to up to 1,700 cfs if conditions in the watershed and forecasts indicate the potential for a major flood event. Increasing this initial diversion flow would provide a higher level of flood risk reduction to Walla Walla by conveying more floodwater through the system prior to beginning diversions, but could also increase the amount of, or frequency of, flood damages in limited areas downstream of the project. The precise operational changes needed to optimize flood risk reduction benefits will be further defined later in this study process.

6.13 RESIDUAL RISK

Flood risk to people and structures at any location within a floodplain is a function of the flood hazard at the location and the extent of exposure and vulnerability to the flood hazard. Residual risk is the flood risk that remains even after the TSP is in place. It is the exposure to loss remaining after other known risks have been countered, factored in, or eliminated. The project will not be able to eliminate all flood risks to life and property. The modeled residual risk for the TSP is equivalent to average annual flood damages of $771,090.

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SECTION 7 - REGIONAL ECONOMIC DEVELOPMENT (RED)

The positive effects of the project on the region's income are equal to the sum of the National Economic Development (NED) benefits that accrue to the region, plus transfer of income from outside the region. The regional economic development (RED) account registers changes in the distribution of regional economic activity that result from each alternative plan. Regional economic development considerations are factors affecting the Walla Walla and surrounding area regional economy while not necessarily affecting national economic outputs. Several such effects in this study would occur if no action was taken to reduce the flood threat. This lack of action would loom in the area's business climate. RED effects resulting from this and other factors would include the following:

7.1 THREATS TO EXISTING LOCAL/REGIONAL BUSINESSES

(Probable adverse income and jobs impacts) - Businesses in and around the Mill Creek study area would be threatened by multiple factors related to flood risk, including (a) periodic flood damage; (b) frequent business closures; (c) employee safety during flood events; (d) the cost of flood insurance requirements; and (e) stiff building codes, that would work against firms needing to expand. In large flood events, business shutdowns can last for weeks, causing sizable and even ruinous production losses. Some production losses with potential to represent unquantified NED losses could occur with local municipal utilities.

7.2 THREATS TO ECONOMIC DEVELOPMENT PROSPECTS

(Probable adverse income and jobs impacts) - If no project is completed in the region, this could discourage new development and growth in the form of businesses migrating into the city or region or the development of new areas. Businesses may leave the Mill Creek study area, be reluctant to expand, or refuse to locate in the area due to concerns over potential flood damages. Large companies considering moving into the study area, bringing job concentrations with them, may be less inclined to do so in a flood-prone area.

7.3 RESIDENTIAL FLOOD INSURANCE PREMIUM COSTS

(Probable adverse income impact) – If no action is taken, residents could become subject to onerous flood insurance requirements.

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SECTION 8 - OTHER SOCIAL EFFECTS (OSE)

Other social effects under without-project conditions include, but are not limited to, the following:

8.1 PUBLIC SAFETY

(Possible adverse impacts on human life) – Based on the HEC-LifeSim modeling there are nearly 9,400 residents and more than 2,000 structures in the study area at risk. Danger could take the form of drowning, electrocution, and illness from exposure to contaminated flood waters. In accordance with ER 1105-2-101, 8.f, as assessment of potential life loss is required.

8.2 PUBLIC HEALTH

(Probable adverse impacts on health) –Residents living in the floodplain may suffer from chronic stress due to worrying about future flooding and about how a flood could affect their finances and daily activities. Chronic stress can affect mental, emotional, and physical health and quality of life.

8.3 RISK TO VULNERABLE POPULATIONS

(Probable adverse socioeconomic impacts) – Some socioeconomic groups may have higher social vulnerability to flood events, such as the aged, poor, and minority populations. These populations may not be able to recover from flooding events as well as others, leading to worse outcomes.

8.4 THREATS TO REDEVELOPMENT

Also touched on above under RED impacts; if redevelopment is indeed hampered, it would negatively affect aesthetic values (removal of blight followed by orderly, planned redevelopment) and historical values. Impacts to this community amenities could affect community cohesion and quality of life. Should flooding disrupt these areas, there may be temporary and, to some extent, permanent losses in social cohesion among some residents in the Mill Creek study area.

8.5 THREATS TO CRITICAL INFRASTRUCTURE

Another aspect of other social effects is potential impacts to critical infrastructure under flood events. Homeland Security Infrastructure Program Gold is a database of critical facilities and was used to determine critical infrastructure in the Mill Creek study area. Table 8-1 lists the type and quantity of critical infrastructure that are potentially impacted in the 0.1 percent AEP flooded area under without-project conditions. As the table indicates, 195 critical infrastructure points are potentially impacted under the without-project conditions.

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Table 8-1. Critical Infrastructure in the Study Area

Damage Category	Total
Agriculture	1
Chemicals	8
Communications	7
Education	25
Emergency Services	33
Energy	14
Law Enforcement	5
Mail Shipping	5
Manufacturing	10
Public Venues	23
Transportation Air	3
Transportation Ground	59
Water Supply	2

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